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OUTBREAK OF WESTERN CUCUMBER MOSAIC ON SUGAR BEETS[1]

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SUMMARY

Western cucumber mosaic occurs in the interior regions of California, and not in the coastal fog belt.

The symptoms of western cucumber mosaic on naturally infected sugar beets are: large, pale-yellow chlorotic areas; white or green veinbanding or interveinal chlorosis; blisterlike elevations on younger leaves, often accompanied by distorted midribs and veins or by outward-rolled leaf margins; and deformed or twisted young leaves.

The green peach aphid, *Myzus persicae* (Sulzer), is the most important vector of the virus to sugar beets. The bean or dock aphid, *Aphis rumicis* Linnaeus, rarely transmits the virus to beets.

Systemic infection was obtained with 20 per cent of the beets inoculated by the green peach aphid and 26 per cent of those mechanically inoculated.

INTRODUCTION

A serious outbreak of western cucumber mosaic on sugar beets occurred near Firebaugh and Mendota, in the middle San Joaquin Valley, California, in 1940. Economic and ornamental flowering plants and weeds of many species showed severe symptoms of the disease. Enormous flights of the green peach aphid, *Myzus persicae* (Sulzer), from the plains and foothills of the Inner Coast Range occurred in the beet fields that year. Ladybird larvae and adult beetles devouring aphids were teeming in the beet fields during the spring.

A similar relation between heavy aphid population and an outbreak of another virus disease occurred in 1927. During the spring of that year, aphids were extremely abundant and destroyed most of the pasture vegetation grow-

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ing on the plains and foothills of the Inner Coast Range in the middle and northern San Joaquin Valley, as reported in a previous paper (Severin, 1933).[4] After the pasture vegetation became wilted and began to dry, swarms of winged aphids flew into the cultivated areas. That year most of the sugar beets in the middle and northern San Joaquin Valley developed symptoms of sugar-beet mosaic; however, no beets showing symptoms of western cucumber mosaic were found. The beet leafhopper, *Eutettix tenellus* Baker, could not have been an important factor in 1927 because its food supply was destroyed in March, before most of the nymphs had acquired the winged stage.

Freitag (1941) reported that ten species of aphids readily transmitted western-cucumber-mosaic virus to 104 of 271 squash plants.

Bennett (1944) described and illustrated yellowish primary lesions on sugar beets after juice inoculation with a strain of cucumber mosaic from sugar beets in the vicinity of Mendota. Systemic infection did not result from such lesions, he reported; but did result from inoculation by *Myzus persicae*.

The present paper reports observations on and experiments with western-cucumber-mosaic virus from 1940 to 1947. The phases investigated were distribution of the disease, methods of transmission of the virus, symptoms of the disease, and recovery of the virus. The symptoms are similar to those of celery calico and common cucumber mosaic on the leaves of sugar beets. To facilitate distinguishing them, a study was made of symptoms of the latter two diseases; this study is reported in the companion paper (Severin, 1948).

GEOGRAPHICAL DISTRIBUTION

The western-cucumber-mosaic virus occurs only in the interior regions of California and not in the coastal fog belt. Entomologists of the Spreckels Sugar Company made surveys of the sugar-beet fields in the southern and northern San Joaquin Valley and in the Sacramento Valley; but they found only an occasional plant to be naturally infected with this disease in 1940 and later years. An examination of the beet fields in the coastal fog belt in the Santa Clara Valley during the 1940 outbreak of the disease failed to show a single beet infected with this cucumber-mosaic virus.

SYMPTOMS

On Experimentally Infected Beets. On leaves of experimentally infected sugar beets in the greenhouse, the sequence of symptoms of western cucumber mosaic is as follows: Beet leaves 7 to 10 days after inoculation show numerous, large, pale-yellow, chlorotic areas, 5 to 10 mm in diameter, each with a circular, chlorotic center enclosed in a narrow dark ring, and with the margins of the areas diffusing into the surrounding green portions of the leaf (fig. 1, *A*). On some inoculated outer leaves, small, chlorotic spots develop among the large yellow areas, and white veinbanding of the midrib and veins occurs (fig. 1, *B*). Later, each yellow area becomes surrounded by a green or yellow ring, and the center becomes purple or pink (fig. 1, *C*). Accompanying these symptoms, veinbanding (fig. 2, *A*) or a reticulate pattern (fig. 2, *B*) may develop. Each circular, chlorotic area becomes necrotic (fig. 1, *D*) and persists after the leaf becomes dry (fig. 2, *C*). Necrosis of the midrib and lateral veins

[4] See "Literature Cited" for citations, referred to in the text by author and date.

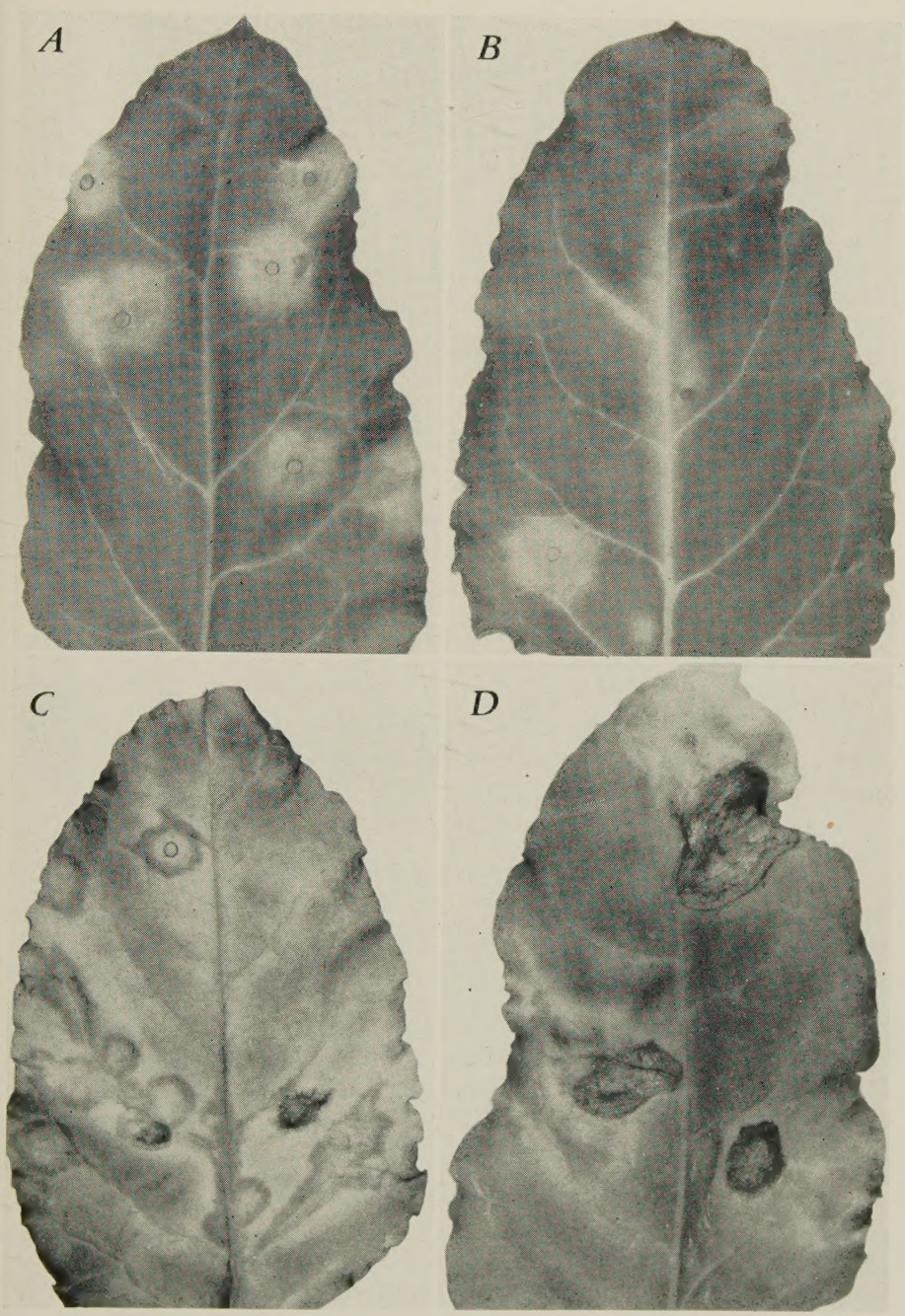

Fig. 1. Symptoms of western cucumber mosaic on leaves of experimentally infected sugar beets: *A*, large, circular, pale-yellow, chlorotic areas with margins diffusing in surrounding green portion; *B*, small and large yellow areas and white veinbanding of midrib and veins; *C*, green or yellow rings enclosing pale-yellow areas with purple or pink centers; *D*, necrotic, circular areas, formerly yellow.

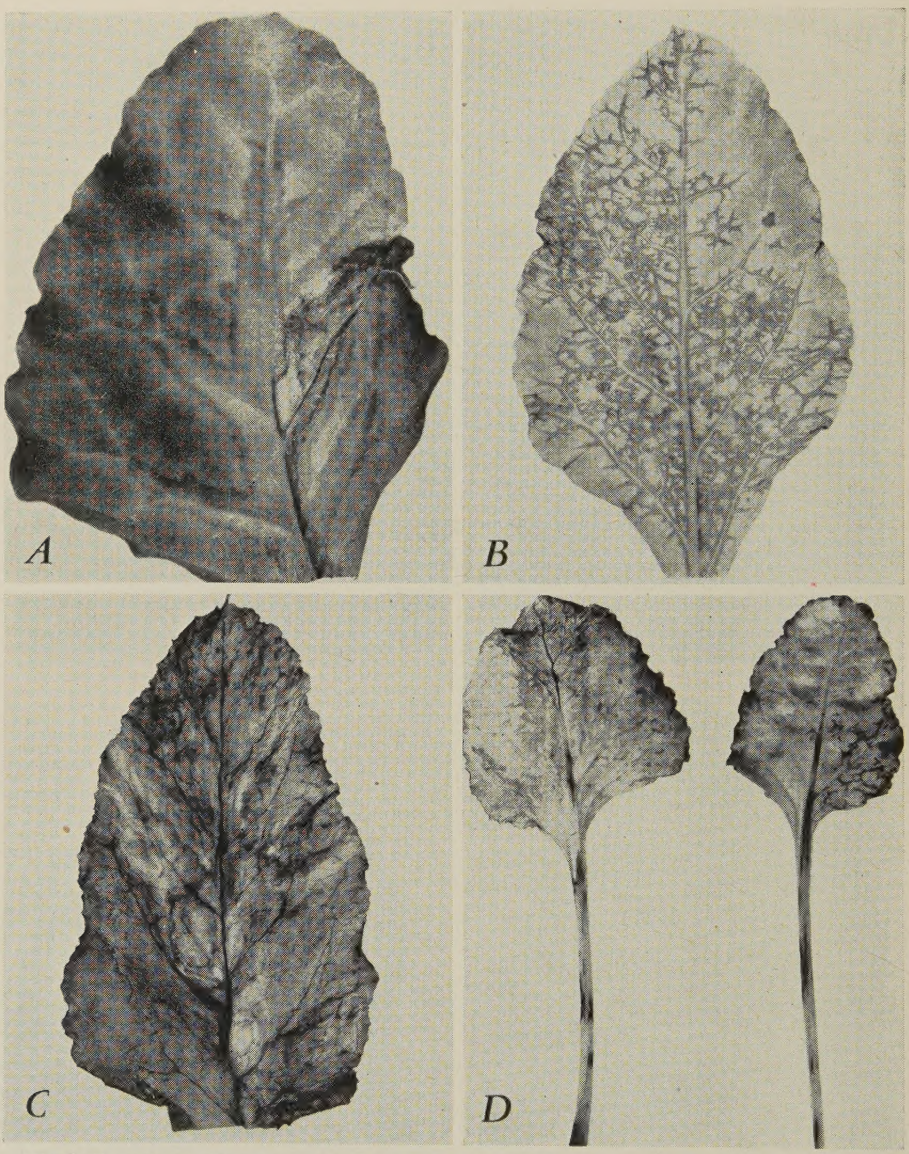

Fig. 2. Symptoms of western cucumber mosaic on leaves of experimentally infected sugar beets: *A*, necrosis and veinbanding; *B*, reticulate pattern; *C*, dried leaf showing necrotic circular areas; *D*, necrosis of petioles, midribs, and rings surrounding chlorotic areas.

occurs (fig. 2, *D*). When infection is systemic, blisterlike elevations develop on the younger leaves. This symptom is like that shown for natural infection in figure 4, and is a reliable indication of systemic infection (page 529). It also helps to distinguish this disease on mechanically inoculated beets from celery calico and common cucumber mosaic, which show somewhat similar chlorotic symptoms. This is further discussed in the companion paper (Severin, 1948).

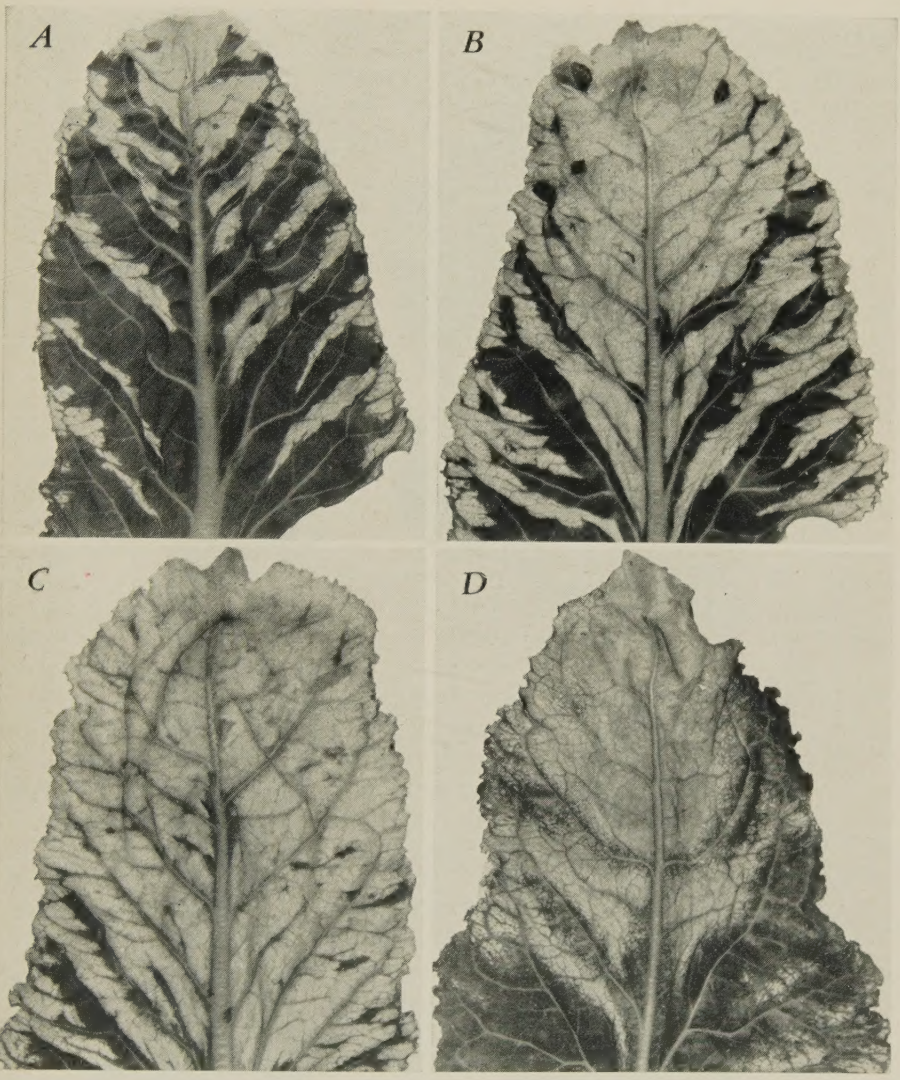

Fig. 3. Symptoms of western cucumber mosaic on young leaves of naturally infected sugar beets: *A*, white or green veinbanding; *B*, chlorosis of apical portion of leaf, interveinal chlorosis, and green veinbanding; *C*, chlorosis of most of the leaf, interveinal chlorosis, and green veinbanding; *D*, chlorosis of upper half of leaf showing interveinal chlorosis, and green, reticulate veinbanding.

On Naturally Infected Beets. Striking symptoms on naturally infected sugar beets, when viewed from the roadside, are the general yellowing of the outer leaves and dark-green intermediate and younger leaves. A closer examination of the outer yellow leaves shows numerous circular, chlorotic areas, like those in experimentally infected beets (fig. 1, *A*); on old outer and on dried leaves these are necrotic. White or green veinbanding or interveinal chlorosis occurs on the intermediate or younger leaves (fig. 3, *A*, *B*, *C*).

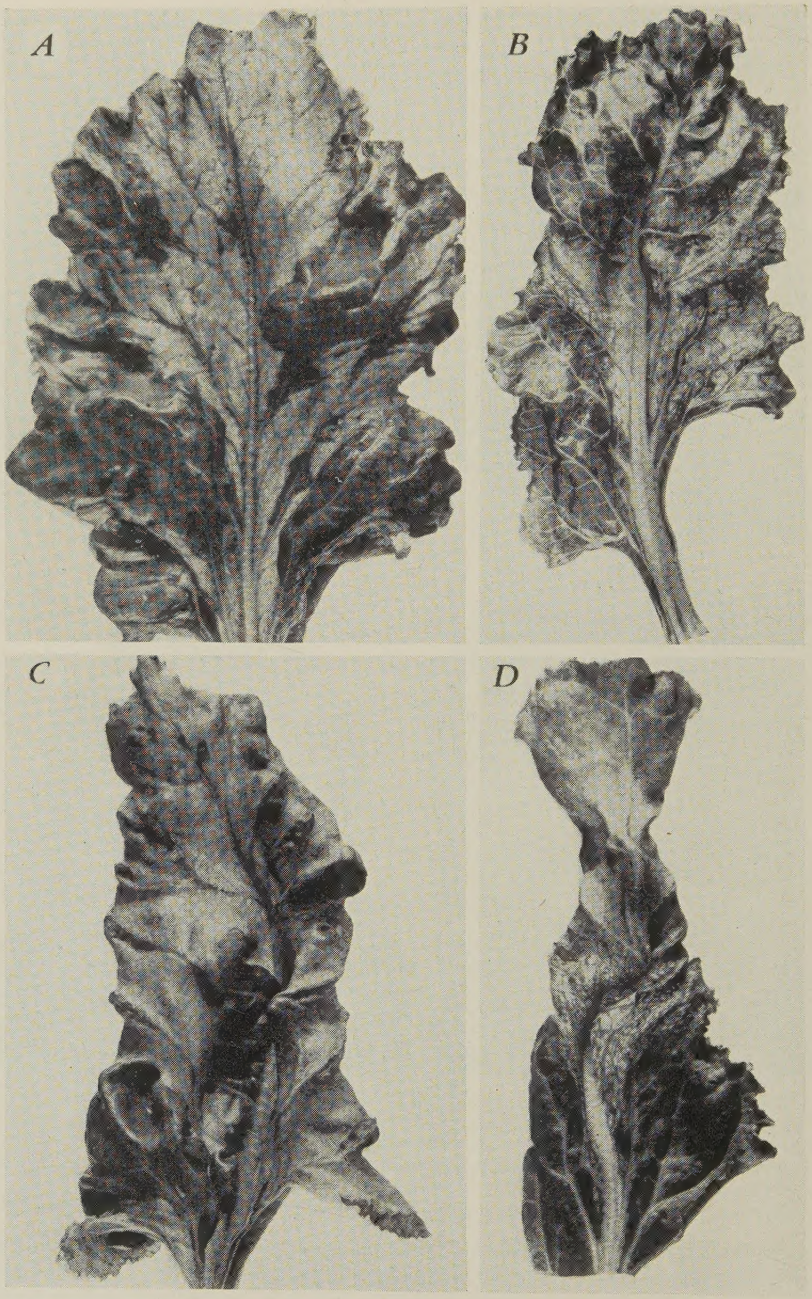

Fig. 4. Symptoms of western cucumber mosaic on leaves of naturally infected sugar beets: *A*, large, green, blisterlike elevations on intermediate leaf; *B*, lower surface of blistered young leaf showing distorted midrib and some of the veins; *C*, outward-rolled margins of blistered young leaf; *D*, deformed young leaf with corkscrew twist. All of the leaves in this figure show chlorosis; but blistering may appear on such intermediate and younger leaves before chlorosis is evident.

Chlorosis begins from the apical portion of the leaf and spreads toward the basal margin (fig. 3, *B*, *C*), with green or reticulate green veinbanding (fig. 3, *D*). A prominent symptom on many of the intermediate and younger leaves is numerous, dark-green, blisterlike elevations (fig. 4, *A*), which may persist after chlorosis of the leaf occurs. The midribs and veins of blistered leaves are frequently distorted (fig. 4, *B*). The margins of the younger, blistered leaves may be rolled outward (fig. 4, *C*). The young leaves may be deformed (fig. 4, *C*), sometimes with a corkscrew twist (fig. 4, *D*).

TRANSMISSION AND RECOVERY OF THE VIRUS

Aphid Vectors. Several species of aphids were tested as vectors of western-cucumber-mosaic virus; the methods used have been described previously (Severin and Freitag, 1938). The following species, reported to occur on beets under natural conditions (Gillette and Palmer, 1934; Patch, 1938), proved to be vectors:

Cotton or melon aphid, *Aphis gossypii* (Glover)
Bean or dock aphid, *Aphis rumicis* Linnaeus
Green peach aphid, *Myzus persicae* (Sulzer)

The green peach aphid is the most important vector of the virus to sugar beets. The bean aphid rarely transmits the virus to beets. The cotton aphid is an efficient vector of the virus to melons and cucumbers. The potato aphid, *Macrosiphum solanifolii* (Ashmead), which also occurs on beets, has not been tested as a vector of this disease.

Mechanical Inoculation Compared with Aphid Transmission. Except where otherwise indicated, the virus was transmitted by mechanical inoculation with the carborundum method (Rawlins and Tompkins, 1936); the expressed sap from sugar beets and other host plants was used.

Mechanical inoculation was compared with the transmission of the virus by the green peach aphid, *Myzus persicae*. The formation of blistering on the youngest leaves of beet seedlings was used as the criterion of systemic infection (see next paragraph). A large population of aphids was reared on 7 sugar beets showing blisterlike elevations on the youngest leaves. Five lots of 20 aphids each were transferred from each diseased plant to healthy beet seedlings, 1 lot to a seedling. The virus extract from each infected plant, on which the aphids had fed, was also inoculated mechanically into 5 healthy beet seedlings. Blistering on the youngest leaves developed on 7 of 35 beets, or 20 per cent, inoculated by the green peach aphid; and on 9 of 35 beets, or 26 per cent, mechanically inoculated. Contrary to Bennett's (1934) results with juice inoculations, previously mentioned, the type of infection was systemic with mechanical inoculation as well as with aphid transmission.

Recovery of the Virus. When the outer leaves of large beets were inoculated, symptoms developed on them; but blistering appeared on the youngest leaves in only about one fourth of the plants. When such blistering did appear, the virus was recovered from the outer, intermediate, and inner leaves of naturally and experimentally infected sugar beets and transferred to healthy sugar beets by mechanical inoculation. When it did not appear, the virus was recovered only from the outer, inoculated leaves showing symptoms. Thus blistering proved to be a reliable criterion of systemic infection.

HOST RANGE, NATURAL INFECTION

The following economic plants were demonstrated to be naturally infected with the virus:

Chenopodiaceae:

Sugar beet, *Beta vulgaris*
Garden or red beet, *Beta vulgaris*
Swiss chard, *Beta vulgaris* var. *cicla*
Spinach, *Spinacia oleracea*

Compositae:

Lettuce, *Lactuca sativa*

Cucurbitaceae:

Honey Dew melon, *Cucumis melo* var. *inodorus*
Cucumber, *Cucumis sativus*
West Indian or bur gherkin, *Cucumis anguria*

Solanaceae:

Tomato, *Lycopersicon esculentum*

Umbelliferae:

Celery, *Apium graveolens* var. *dulce*

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SYMPTOMS OF ADDITIONAL CUCUMBER-MOSAIC VIRUSES ON SUGAR BEETS[1]

HENRY H. P. SEVERIN[2]

SUMMARY

Celery calico occurs on celery and on some other host plants in the interior regions and in the fog belt of California; but has not yet been found on sugar beets here. In mechanically inoculated sugar beets, the type of infection is local.

The virus of common cucumber mosaic is not known to occur naturally in California. In mechanically inoculated sugar beets, the type of infection is local.

Symptoms of these two diseases on mechanically inoculated sugar beets resemble those of western cucumber mosaic, which does occur on this host plant in California. In all three, chlorotic areas, veinbanding, and necrosis occur. The first symptom of celery calico—large, irregular, pale-green areas on the leaves—serves to distinguish it from common cucumber mosaic. Common cucumber mosaic can be distinguished from both celery calico and western cucumber mosaic by the first symptom—small, white dots with pinpoint necrotic centers; later by small, rust-colored necrotic centers in circular, chlorotic areas; still later by holes in some leaves caused by the dropping out of the necrotic centers. Neither celery calico nor common cucumber mosaic show, in mechanically inoculated beets, the blisterlike elevations that characterize systemic infection with western cucumber mosaic.

INTRODUCTION

The symptoms of celery calico and common cucumber mosaic closely resemble those of western cucumber mosaic. To facilitate distinguishing them, studies were made of the symptoms of all three diseases in experimentally infected sugar beets. This paper describes celery-calico and common-cucumber-mosaic symptoms on that host plant. Symptoms of western cucumber mosaic on experimentally and naturally infected sugar beets are described in the first paper of this issue (Severin and Freitag, 1948).

A number of references appear in the literature concerning the transmssion of common cucumber mosaic or strains of this virus to beets (*Beta vulgaris*). Johnson (1930)[3] inoculated Crosby's Egyptian garden beet with common cucumber mosaic types 1 and 2, and necrotic rings ⅛ inch in diameter developed on the rubbed leaves 10 days after inoculation. These rings increased to ¼ inch in diameter, at which time they were composed of alternate bands of necrotic and red tissues.

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Hoggan (1933) demonstrated that local symptoms resulted from mechanical inoculation of sugar-beet leaves with the common-cucumber-mosaic virus, but systemic infection was not secured. When the green peach aphid (*Myzus persicae*) and the potato aphid (*Macrosiphum solanifolii*) were confined to a single sugar-beet leaf, local lesions developed. The virus appears unable to pass from a single infected leaf of this host to other parts of the plant. When the infective aphids were allowed to feed freely on the foliage of young sugar beets, systemic infection was readily obtained; she suggests that this may possibly have resulted from a direct introduction of virus at or near the growing point of the shoot, the virus perhaps multiplying at this point and forming a source of infection for all subsequent growth.

Price (1940), in his table on species of plants tested for susceptibility to six viruses, lists *Beta vulgaris* as susceptible to the cucumber-mosaic virus (*Marmor cucumeris* H. var. *vulgare* H., *judicis* H., and *vignae* H; mosts tests with the ordinary strain, *vulgare*).

MATERIALS AND METHODS

The common-cucumber-mosaic virus was kindly sent to me by James Johnson, University of Wisconsin. The original source of the celery-calico virus was naturally infected celery obtained near Milpitas in the Santa Clara Valley. The viruses were maintained by repeated mechanical inoculation of various host plants; and also the virus extract was kept overwinter in cold storage at −18° C.

The method of mechanical inoculation used is that described by Rawlins and Tompkins (1936). Shortly after inoculation, the carborundum and the inoculum were washed from the leaves with water. No tests of insect transmission were included in these experiments.

CELERY CALICO

Celery calico has been found on celery in all of the large celery districts in California (Severin and Freitag, 1938). The disease occurs in the interior regions and in the fog belt of the state. The distribution of celery calico on naturally infected perennial delphiniums has been reported in a previous paper (Severin, 1942*a*). Other naturally infected host plants include larkspurs (Severin, 1942*b*) and pansies and violas (Severin, 1947). Up to the present time, no attempt has been made to find sugar beets naturally infected with this disease. It could easily pass unnoticed because the symptoms appear only on the inoculated leaves.

Symptoms. The first symptom of celery calico on the leaves of sugar-beet seedlings, 3 to 9 days after inoculation (4 to 15 days on large beets), is large, irregular, pale-green areas (fig. 1, *A*), which diffuse into the green tissue. (This symptom serves to distinguish this disease from common cucumber mosaic.) Later, these become circular yellow areas, 11 to 15 mm in diameter, each with a pale chlorotic center (fig. 1, *B*). Chlorotic veinbanding of a portion of the midrib and some of the veins may occur (fig. 1, *B*). Chlorosis spreads gradually over the entire leaf. Irregular green, later chlorotic, rings surround the circular yellow areas (fig. 1, *C*); these enlarge, coalesce, and become irregular in shape (fig. 1, *D*). The fused rings become necrotic (fig. 2, *A*), usually

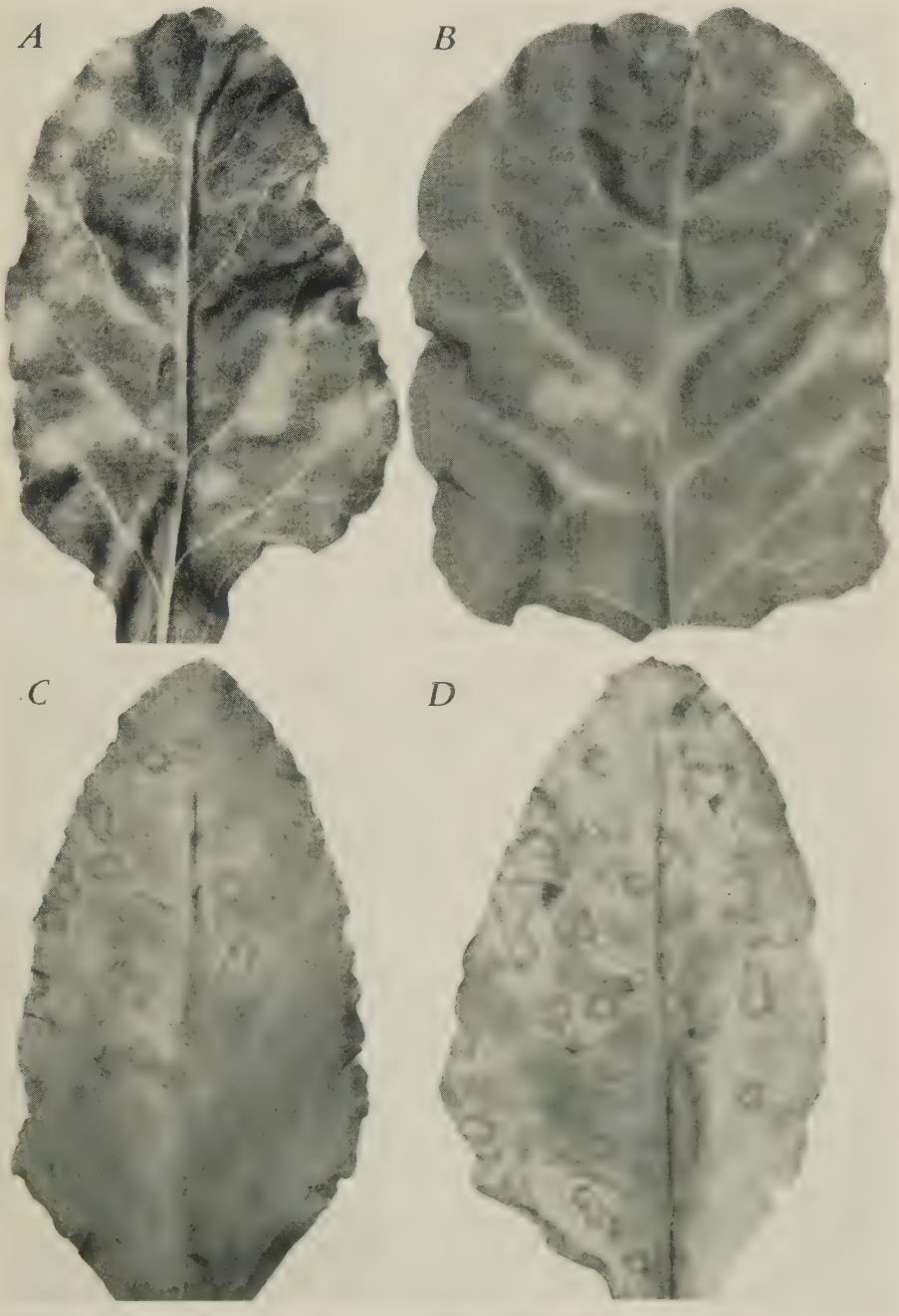


Fig. 1. Symptoms of celery calico on experimentally infected sugar beets: *A*, circular, chlorotic areas with margins diffusing in green areas; *B*, circular, chlorotic areas, some showing pale, circular center, veinbanding of portion of midrib and some of the veins; *C*, irregular, green, later yellow, rings surrounding pale-green areas which become chlorotic; *D*, yellow rings coalescing.

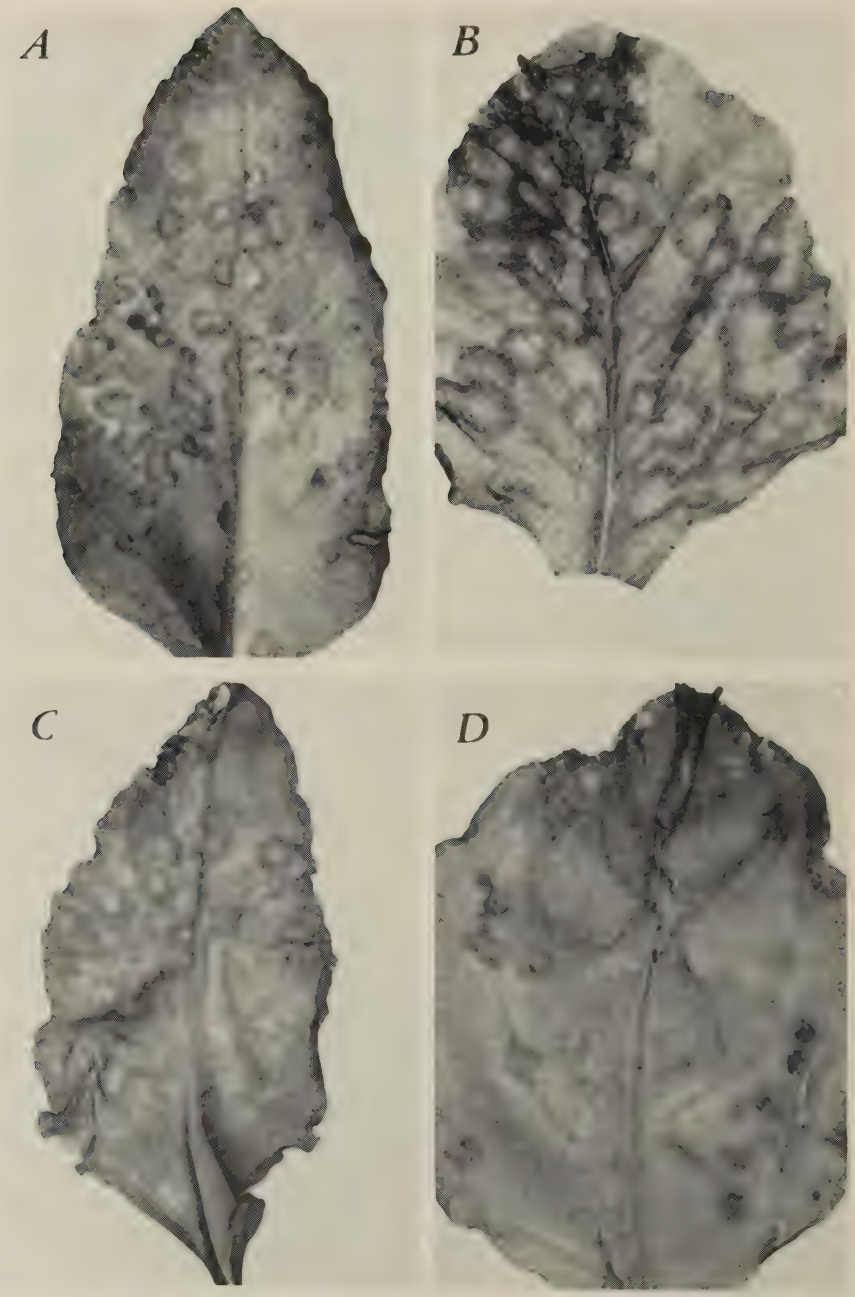


Fig. 2. Symptoms of celery calico on leaves of experimentally infected sugar beets: *A*, fused, necrotic rings; *B*, necrosis of apical portion of leaf, midrib, and veins, and necrotic rings still evident in dried portion of leaf; *C*, yellowing of upper half of leaf showing necrotic rings; *D*, necrosis of rings and enclosure. Note that the chlorotic areas in this disease lack the small rust-colored centers that are often present in common cucumber mosaic (see fig. 5, *A*).

after the leaf becomes yellow (fig. 2, *B, C*); and finally the entire circular areas become necrotic (fig. 2, *D*) and are still evident on the dried leaves (fig. 2, *B*).

Recovery of the Virus. The type of infection by mechanical inoculation, was local, not systemic. The virus was recovered only from the inoculated leaves and transferred to healthy sugar beets, cucumbers, celery, and Turkish tobacco (*Nicotiana tabacum*) by mechanical inoculation.

COMMON CUCUMBER MOSAIC

Common cucumber mosaic is not known to occur on any host plant in California.

Symptoms. The first symptom of common cucumber mosaic on sugar-beet leaves, 4 to 9 days after inoculation, is numerous, white dots (fig. 3, *A*), each with a pinpoint, necrotic center. These dots gradually enlarge (fig. 3, *B*) and each retains the pinpoint, necrotic center. The white, circular areas fuse (fig. 4, *A*). Green rings, 3 to 8 mm in diameter, surround pale, chlorotic areas, with a small, circular central area (fig. 4, *B*) and a necrotic center. Within the next 2 or 3 days the green rings become yellow, enclosing chlorotic areas, each with a small central, circular area with a necrotic center (fig. 5). Sometimes concentric green and yellow rings surround chlorotic areas, each with a rust-colored, necrotic center. Frequently the rings coalesce (fig. 5, *C, D*). The chlorotic areas surrounded by rings may become brown, drop out, and leave

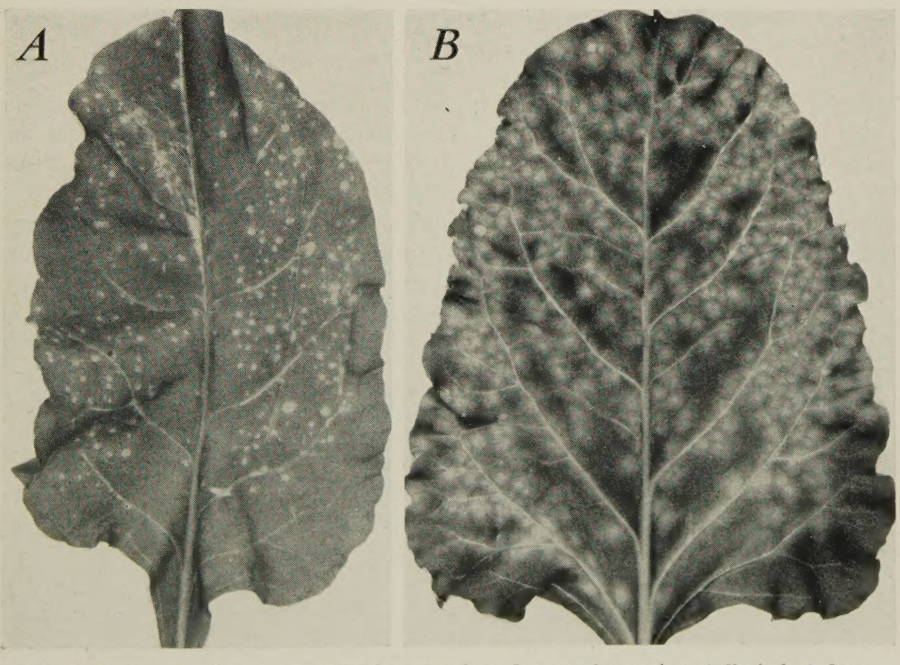


Fig. 3. Symptoms of common cucumber mosaic on leaves of experimentally infected sugar beets: *A*, numerous white dots; *B*, dots enlarged to form white, circular areas. These dots, the first symptom to appear in this disease, do not occur in celery calico or in western cucumber mosaic.

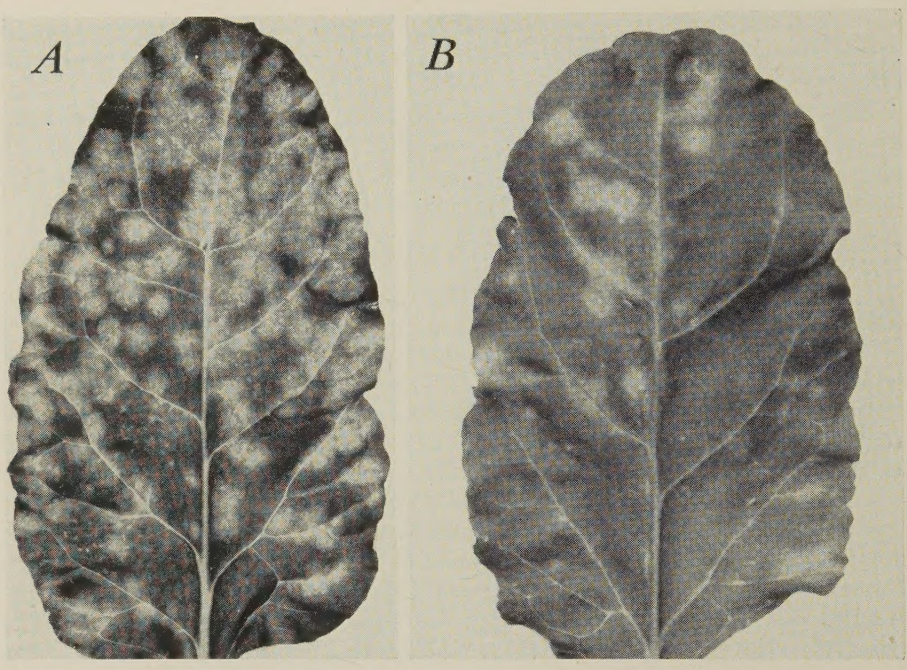


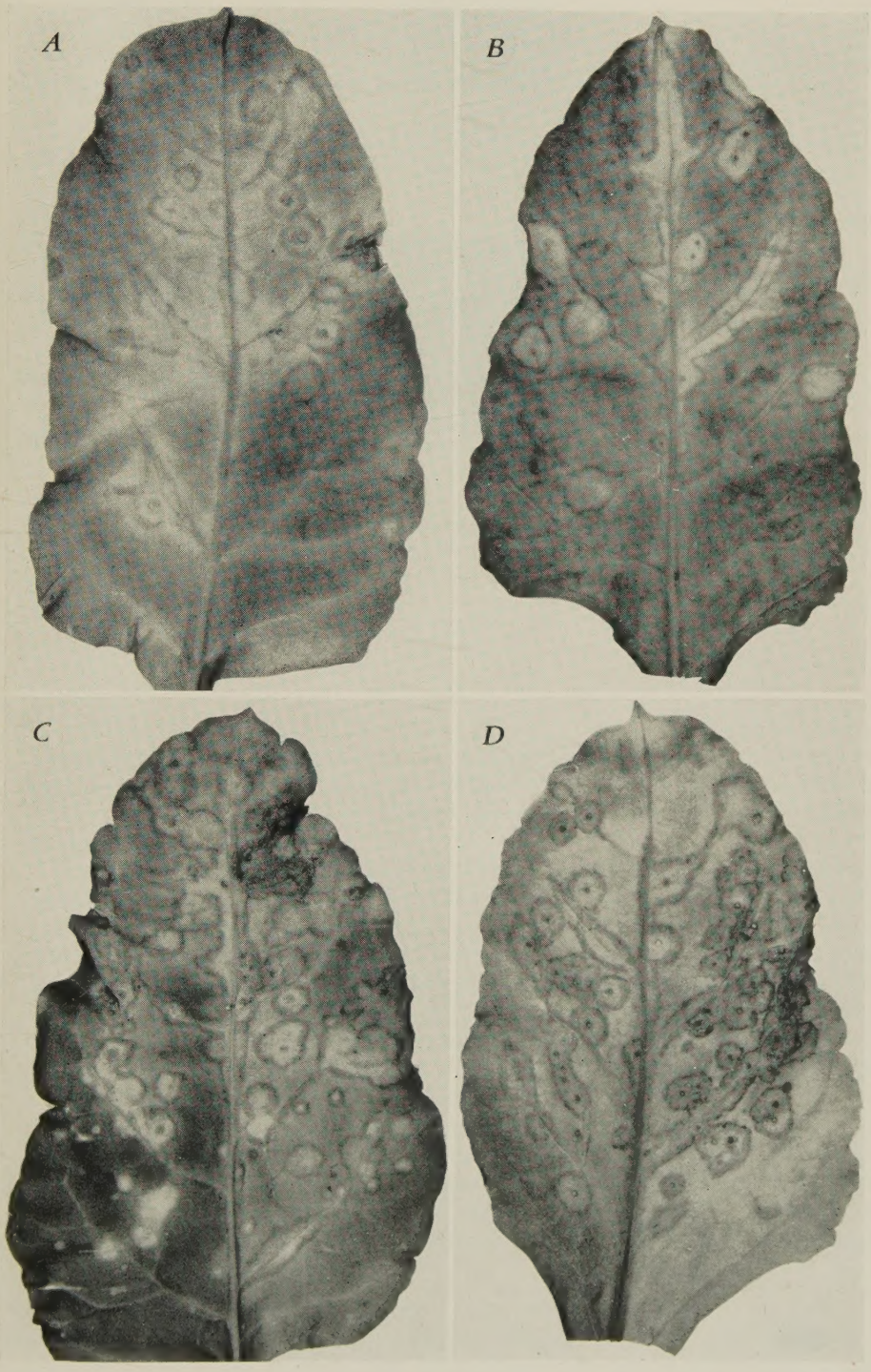
Fig. 4. Symptoms of common cucumber mosaic on leaves of experimentally infected sugar beets: *A*, fusion of white circular areas; *B*, green rings surrounding chlorotic areas, each with a small, central, circular spot.

holes in the leaf. Yellow veinbanding along part of the midrib and lateral veins develops (fig. 5). Sometimes forked chlorotic tissue extends from the rings (fig. 5, *A*, *B*). In the later stage of the disease, necrosis of the rings occurs, and the rings are still evident on the dried leaves.

The symptoms that are useful in distinguishing this disease from celery calico and western cucumber mosaic are the small white dots with pinpoint necrotic centers (fig. 3, *A*)—the first symptom to appear; in a somewhat later stage, the small rust-colored necrotic centers of some chlorotic areas (fig. 5, *C*); and still later the holes in some leaves caused by the dropping out of the necrotic centers.

Recovery of the Virus. The virus was recovered only from the inoculated leaves and transferred to healthy sugar beets, cucumbers, and celery by mechanical inoculation. The type of infection was local and not systemic, agreeing with the results Hoggan (1933) obtained with mechanical inoculation of this virus.

Fig. 5. Symptoms of common cucumber mosaic on leaves of experimentally infected sugar beets: *A*, yellow rings with large, necrotic, rust-colored centers and yellow veinbanding; *B*, fusion of rings, some with two necrotic centers, and yellow veinbanding of midrib and lateral veins; *C*, *D*, fusion of many necrotic rings with 1 to 5 necrotic centers, and veinbanding.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